"*Reprinted from the Canadian Record of Science, Jan. and April*, 1896."

Currents and Temperatures in the Gulf of St. Lawrence.

By Andrew T. Drummond, LL.D.

That the cold Arctic or Labrador Current which, in a broad belt, skirts the easterly coasts of Labrador and Newfoundland, sends, when passing the Straits of Belle Isle, a branch westerly into the Gulf of St. Lawrence, influencing thus, the temperature of the water on, not only its northerly coasts, but far up the estuary of the St. Lawrence, has been the hitherto received opinion. This opinion obtained confirmation not only from the presence of icebergs in the Gulf of St. Lawrence 275 miles westerly

of the Straits of Belle Isle, but in the low temperature of the water, both at the surface and at the bottom, as far up the northerly side of the River St. Lawrence as at least Murray Bay, seventy miles below Quebec, the general effect of this low temperature on the vegetation of the immediate coasts being seen in the limited distribution of forest trees and the presence of high northern or semi-Arctic plants. That icebergs were not found farther into the Gulf was not an argument against the existence of a branch current, as the milder atmosphere and warmer surface waters of the land-locked gulf during summer, would, naturally, tell rapidly on the masses of ice, however large, once they were carried well into and beyond the Straits of Belle Isle.

Mr. W. Bell Dawson, who has been commissioned by the Dominion Government to make a survey of the tides and currents of the River and Gulf of St. Lawrence, has, in his report for 1894, raised the question whether there is an uniformly inward current at the Straits of Belle Isle, and whether the currents there are not, in reality, fundamentally tidal, though affected considerably by the direction of the wind in the Straits, and by barometric pressure in the Gulf as well as outside.

Apart from the great scientific interest which attaches to it, the proper settlement of this question is important on account of its bearing on the navigation of the Straits where several large steamships have in recent years been lost. Enveloped in fog as these Straits so frequently are, and their surface dotted at certain seasons with icebergs, it is essential that their currents should be carefully examined and thoroughly understood. Whilst, however, Mr. Dawson's investigations into the direction and force of the current have very great value attached to them, are not the tests made too few in number and carried over too limited an area, to, as yet, enable definite conclusions to be drawn? The nearest point in the Straits to the

Labrador coast, at which tests of the currents were made, was three miles distant, and yet the position in which we would expect to find this cold branch current, if it does exist, is comparatively close to this Labrador coast, where the water is colder and deeper.

An instance to some extent parallel to that of the Gulf St. Lawrence and the Atlantic Ocean is the Black Sea in its relations to the Mediterranean Sea. There is a great body of fresh water poured daily into the Black Sea by the Danube, the Dnieper and other rivers, but even after taking into account the enormous evaporation constantly going on over the broad area which the sea presents, there is a slight outward surface current through the Dardanelles. On the other hand, there is also a current inward which is beneath and saline, and which, Dr. Carpenter explains in the Encyclopædia Britannica, is produced by the outward surface current creating downward and therefore lateral pressure on the Mediterranean waters, causing a current inward through the Dardanelles. Dr. Carpenter adds: "We have here a pregnant instance of the slight differences in level and salinity to produce even rapid movements of considerable bodies of water, and a strong confirmation of the doctrine that differences of density produced by temperature are adequate to give rise to still larger though slower movements of the same kind in the great ocean basins."

As bearing on the subject, Mr. Dawson has taken both surface and deep water temperatures at different points on three cross sections of the Straits of Belle Isle and one cross section at Cabot Straits, between Newfoundland and the Cape Breton coast. These temperatures are very interesting and establish the conclusions that the colder waters are always deflected against the Labrador or northern side of the Straits of Belle Isle, and against the Newfoundland or northern side of Cabot's Straits, whilst the warmer waters press against the southern sides in

both straits. The cold Arctic current itself, in its onward course southward along the North American coast line, is, as we know, always similarly thrown to the right hand or westward side, and exhibits this distinctive feature even where with a greatly modified temperature at the surface, it somewhat parallels the Gulf stream off the southern United States coast. The details of Mr. Dawson's notes show that on the Labrador side of the Straits of Belle Isle, just inside of Belle Isle itself, the thermometric readings at ten fathoms ranged from 35° to 38° F., whilst on the Newfoundland side of the Straits near Cape Bauld they reached as high as 51°. Again, on the south-west side of Newfoundland, near Cape Ray, at the same depth, they indicated 41° to 46° F., whilst towards the Cape Breton side they were as high as 60° to 64° F. Further, at twenty fathoms, the difference in temperature between the north and south sides of the Straits of Belle Isle was 13°, and between the Newfoundland and Cape Breton sides of Cabot Straits 4°. In some cases the variations were very marked. Proceeding from Cape North on the Cape Breton coast to near St. Paul Island, the temperature at ten fathoms fell 24°. Still further, at forty fathoms the general temperature off the Labrador coasts, in the Straits of Belle Isle, was about 30° F., whilst near Cape Bauld, on the opposite coast line, it rose to 33° F. At the same depth in Cabot's Straits variations in the readings were less marked—the range being on both sides between 33 and 34° F.

The inferences which can be drawn, generally, from these temperatures in connection with other facts is that the colder waters deflected against the northerly sides represent the Arctic Current from the Atlantic Ocean, whilst the southerly deflected warmer waters are to be attributed to the Gulf of St. Lawrence. The higher temperatures of the Gulf waters are traceable to two sources —the land-locked character of this great bay, and the

enormous volume of warmer water being daily poured into it by the St. Lawrence and numerous other smaller Canadian rivers. Although the point has not been properly established on both sides of this river's great estuary by thermometric tests, yet it would appear from surface and deep sea readings taken by the writer near Murray Bay on the north coast (46½° F. at surface, 38¼° at 17 fms., and 38½° at 31 fms.—all on 5th August), and from the fact that whilst bathing during the summer season is somewhat exceptional on that side, it is more general on the south coast, that these warmer waters of the River St. Lawrence are also deflected to the southern coast or right hand in their progress towards the sea.

The evaporation over the broad surface of the Gulf must be very great, but does it counterbalance the enormous masses of fresh water which are being constantly poured into it from the Great Lakes and the rivers of Canada? Whether it does so or not, if there is an outward current of warmer water deflected to the southerly side of these two outlets from the Gulf, there must be some fully compensating inward flow of colder water either reversely parallel to it or underneath, just as in the case of the Black Sea. Although claiming that the current at the Straits of Belle Isle is fundamentally tidal in its nature, Mr. Dawson, nevertheless, admits that under normal conditions and when both surface current and undercurrent in the two directions are taken into account, the difference on the average is in favor of a greater inward flow from the east, and that the actual flow throughout the year appears also, on the whole, to be greater in the inward direction from the east than outward from the west. Between Newfoundland and Cape Breton he, however, finds a current running out of the Gulf on the western or Nova Scotia side, and into the Gulf on the eastern or Newfoundland side.

There are other very important considerations which

have also to be taken into account. Wind, as we know, influences currents. On Lake Ontario, it will, when blowing down the lake continuously for some time even pile up the water at the lower end to a height of many inches and create underneath a reverse current. The direct effects produced by winds are, however, not relatively deep, and, therefore, probably hardly have a perceptible influence upon any cold current in the Gulf which underlies warmer waters. Thus in the Straits of Belle Isle, at a depth of thirty to forty fathoms, a high wind from the west may have but little effect on a current from the east. Again, although the great mass of water in the ocean as well as in the land-locked Gulf of St. Lawrence, is swayed backward and forward twice each day, the whole moves together, and it is quite possible to conceive of the currents in these bodies of water maintaining their directions irrespective of the motion of the whole mass, of which these currents form only a part, with different causes for their motion. The rise and fall of the surface, which is the popular notion of the tide, is, Prof. G. H. Darwin has, among other matters, pointed out to me, really the outcome of a small current in the whole fluid, the current being reversed in direction every twelve hours. The subject has an important bearing on the existence of a more or less continuous cold current inwards at the Straits of Belle Isle. The cold current, if it exists at all there, as a definite factor, is to be sought for more as a deep seated than even a surface current, and will be found clinging to the northerly side of the Straits where the deepest channel is also known to exist. How far does the effect of the tide there at forty to fifty fathoms seriously interrupt such a current? It is in this northern part of the Straits where investigations into the undercurrents are still wanted. Mr. Dawson's observations, where they were made outside of the three miles distance from the Labrador coast, show that some

permanent undercurrent does exist, because "during the times that the current ran in fair correspondence with the tides, when the conditions may be considered as normal, the undercurrent was usually stronger than the surface current, when the flow was from the east, and it was always weaker than the surface current, when the flow was from the west." Whatever effect winds and tides do produce at forty fathoms or more would be exerted in favor of this inward undercurrent during a considerable part of the year, since, as a whole, between easterly and westerly influences, that from the east appears to be the stronger of the two throughout the year. As to the relative effects of high pressure areas over the Gulf and over the Atlantic Ocean, off the Labrador and Newfoundland coasts, on the passage of water through the Straits, our information is probably too meagre to enable any opinion as yet to be formed beyond the general fact that for the time a current would be formed.

Another very interesting matter brought to light by Mr. Dawson, and the further investigation of which he recognizes as necessary, is that in the deep sea temperatures, taken on the 16th August, in Cabot Straits, between St. Paul Island and Cape Ray, the temperature—especially towards the former place—which successively fell from 59° at the surface to 31° and 33° F. at fifty fathoms, appeared to rise again to 40½° F. at one hundred and fifty fathoms. Some further careful tests of the density and salinity of these waters as well as further thermometric readings appear to be needed with a view to tracing the influence here of the River St. Lawrence waters. The anomaly can hardly be altogether ascribed to areas of water of different temperatures floating oceanward. In the fresh water of the River St. Lawrence, as it leaves Lake Ontario, where the depth averages about twelve fathoms, there appear in summer to be areas of different temperature, but at any given depth, these areas

as they pass the thermometer do not show differences of temperature exceeding 2° to 3°. We must look largely to other causes for such reversals of the temperature as are indicated near St. Paul's Island.

Jan., 1896.